Contribution ID: **1178** Type: **Regular Poster**

Kinetic simulation of Zonal Flow in Aditya-U Tokamak

Friday, May 14, 2021 12:10 PM (20 minutes)

A. Introduction:

It is well known that plasma transport across magnetic field is largely controlled by the low frequency drift wave fluctuations. Gyrokinetic simulations play an important role in predicting the transport level due to neoclassical physics or turbulence. One of the leading successful methods is the particle-in-cell (PIC) method. A fully three-dimensional global toroidal code using X point (GTC-X) has been developed with cylindrical coordinates and applied to the investigation of zonal flows dynamics in toroidal ion-temperature-gradient turbulence of Aditya-U tokamak (1). For the purpose of this study, the experimental equilibrium profiles are used in all simulations based on the experimental discharge of Aditya-U shot no. 32802 at 50ms.

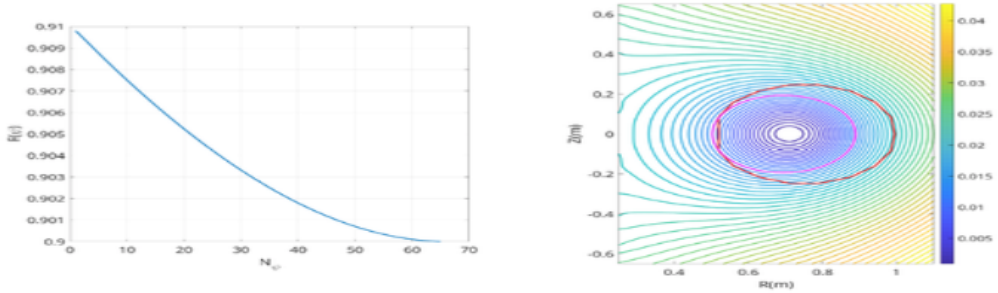

Fig.1 (a) Poloidal current function on uniform flux grid, and (b) Poloidal flux function on rectangular grid for Aditya-U shot no. 32802 at 50ms.

Figure 1: enter image description here

B. Particle Dynamics

We have applied GTC-X (1), to simulate particle dynamics for both fully kinetic particles and guiding centre particles using cylindrical coordinates for Aditya-U geometry. The projection of the fully kinetic and guiding centre passing and trapped particle orbits on the R-Z plane are shown in Fig. 2. Both integrators correctly capture the passing and trapped particle orbits and agree well with each other.

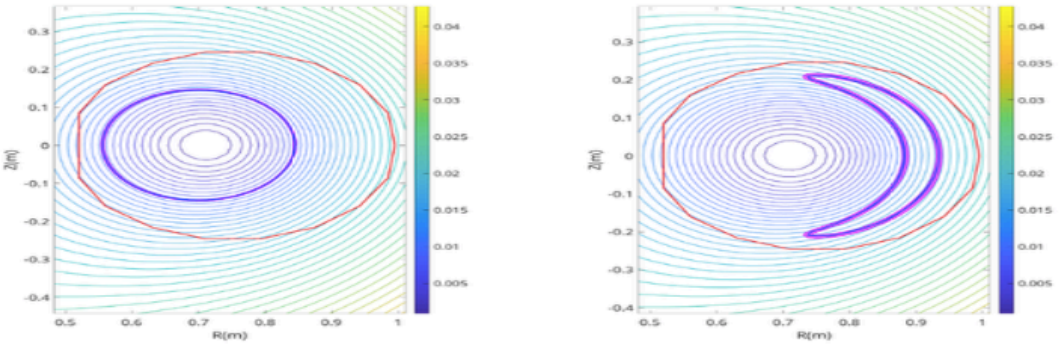

Fig. 2 Passing and trapped orbit of test particles for Aditya-U shot no. 32802 at 50ms

Figure 2: enter image description here

C. Self-consistent Simulation of Zonal flow:
As a benchmark of the capability of GTC-X to reproduce physical phenomena happening in the core region, we carried out self-consistent gyrokinetic simulations of zonal flows in the core region of the Aditya-U tokamak. Zonal flows are low frequency electrostatic modes that are spontaneously generated by turbulence and, in turn, play an important role in regulating the turbulence. The collisionless damping of the zonal electric field to a nonzero steady-state value verifies the famous theory of Rosenbluth and Hinton on the collisionless damping of zonal flows 2. Nonlinear electrostatic simulations have demonstrated that regulation by self- generated zonal flows is the dominant saturation mechanism for the ITG instabilities. We are currently working to verify the ion temperature gradient (ITG) driven microturbulences in the core region of Aditya-U tokamak and understanding the effect of zonal flows on turbulent transport in Aditya-U tokamak.

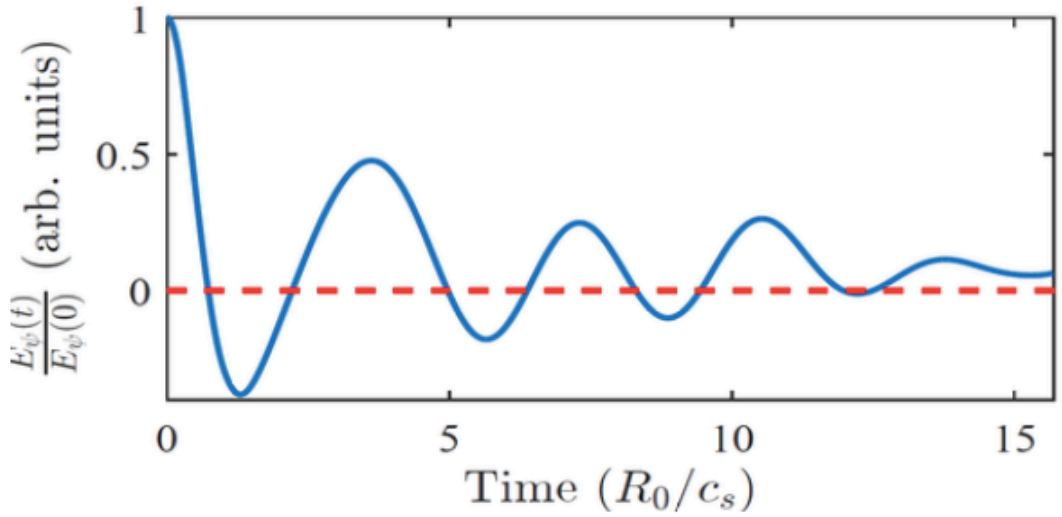

Fig. 3 Zonal flow verification for Aditya-U tokamak.

Figure 3: enter image description here

Acknowledgements:
This work is supported by the Board of Research in Nuclear Sciences (BRNS Sanctioned No. 39/14/05/2018-BRNS), Science and Engineering Research Board EMEQ program (SERB Sanctioned No. EEQ/2017/000164), IISc start-up and Infosys Foundation Young Investigator grant. All the simulations were carried out on ANTYA, an IPR Linux Cluster, Cray XC40 - SahasraT at Supercomputing Education and Research Centre (SERC), IISc.

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Session Classification: P7 Posters 7

Track Classification: Magnetic Fusion Theory and Modelling